IngeniAI

AutoCFD 5

IngeniNetSim: Fast and Scalable Geometric Deep Learning for DrivAerML Prediction

David Massegur & Marc Bernades

19/10/2026

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What is IngeniAI?

IngeniAI

Our Goal

- Accelerate CAE development by integrating advanced AI into your engineering workflow.

Enhance Your Design Process

- Boost CFD, FEA and experimental testing with tailored AI frameworks that unlock deeper insight and faster iterations.

Experts in the Field

- 30+ years of combined experience in Formula 1, aerospace and academic engineering, with PhDs and hands-on expertise in AI.

Already trusting us:

Applus IDIADA

esa European Space Agency

AIAA

VORCAT

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How We Can Help

IngeniAI

Our aim is to help you make the best use of AI:

AI Software

Ingeni NetSim

Physics AI software based on latest tech

Specialised Consultancy

Ingeni Solutions

Tailored AI solutions to your specific demands

Training Courses

Ingeni Learning

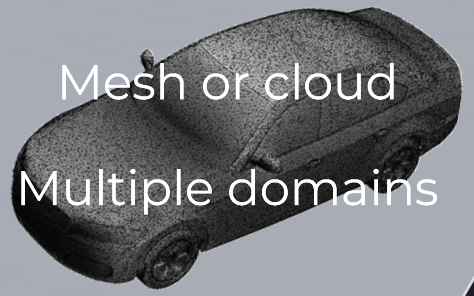
Dedicated training in AI for engineering

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IngeniNetSim Software

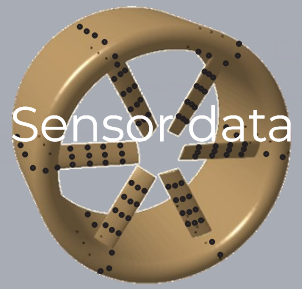
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Inputs



Mesh or cloud

Multiple domains



Sensor data

Global parameters

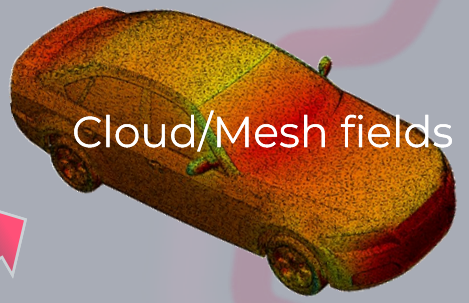
$\alpha_\infty(t), V_\infty(t),$
$Re(t), \omega(t)$ ...

AI model

AI

IngeniNetSim

Predictions



Cloud/Mesh fields

$\oint dS$ Surface integration

Global quantities

$C_L(t), C_D(t), C_M(t)$ ...

Multi-domain Surrogates

RANS → LES Multi-fidelity

Experimental Reconstructions

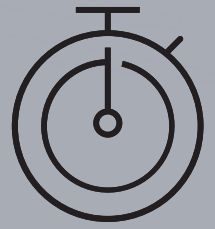
Dynamic analyses

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Software Features

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Why choosing IngeniNetSim?



Fast and Scalable

10M+ grids

Train in hours

Process in seconds



Customisable

Flexible Architecture

Latest Models

Without coding!



Accessible

Low GPU demand

NVIDIA, AMD, MPS

Windows, Linux & Mac

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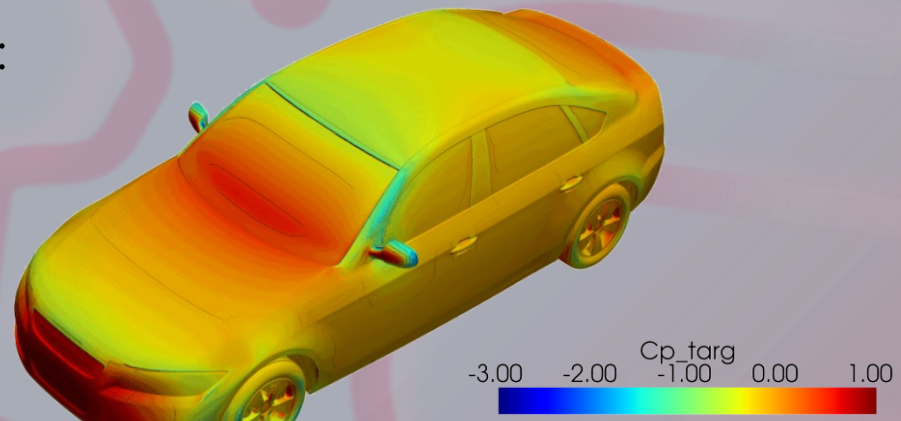
Aims & Objectives

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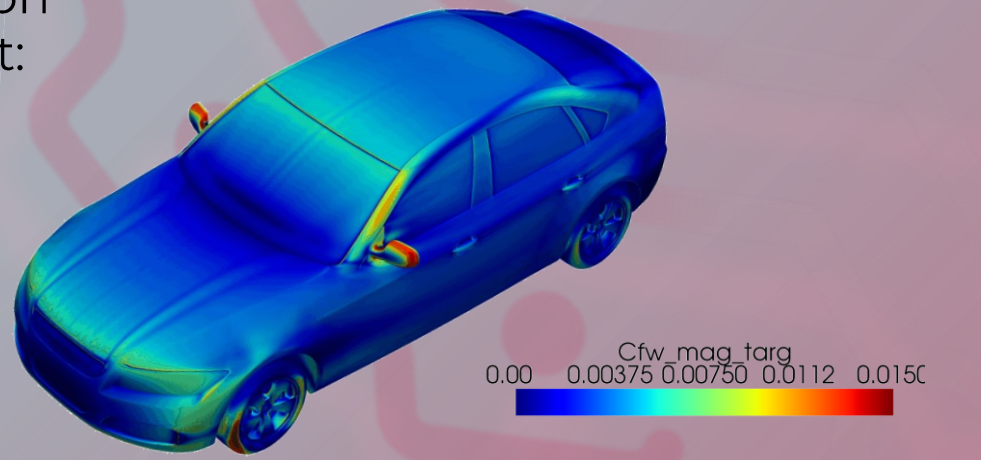
Demonstration of IngeniNetSim on the DrivAerML dataset

- Aerodynamic prediction on the car surfaces:
  - Distributed fields
  - Integrated forces
- Comparison of different modelling approaches.
- Generalisation sensitivity with dataset size reduction.
- Propagate and quantify uncertainty on the predictions.

Pressure coefficient:



Skin friction coefficient:



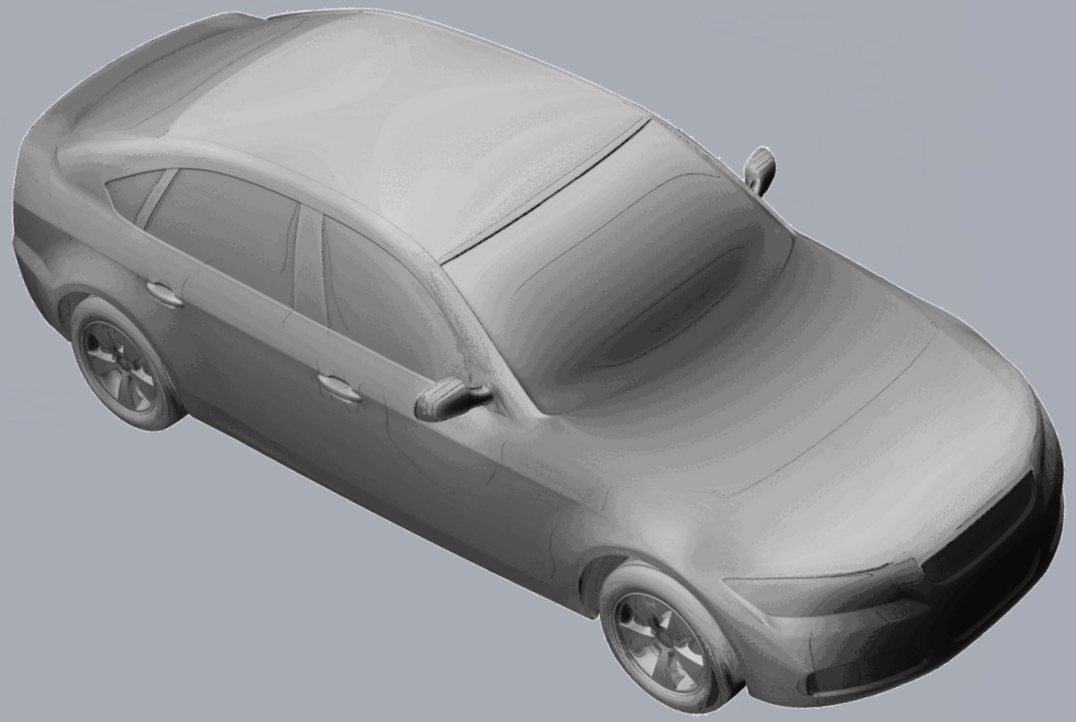
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DrivAerML Dataset

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Test case: 484 different road-car configurations

- DrivAerML – CFD dataset:



- Dataset splits:
  - Full split: 400 train samples
  - Medium split: 133 train samples
  - Scarce split: 67 train samples
  - Super-scarce split: 11 train samples
  - Validation: 34 samples
  - Testing: 50 samples
- Surface data:
  - Meshes with ~10M faces
  - 350 GB data size
  - Pressure, shear stresses

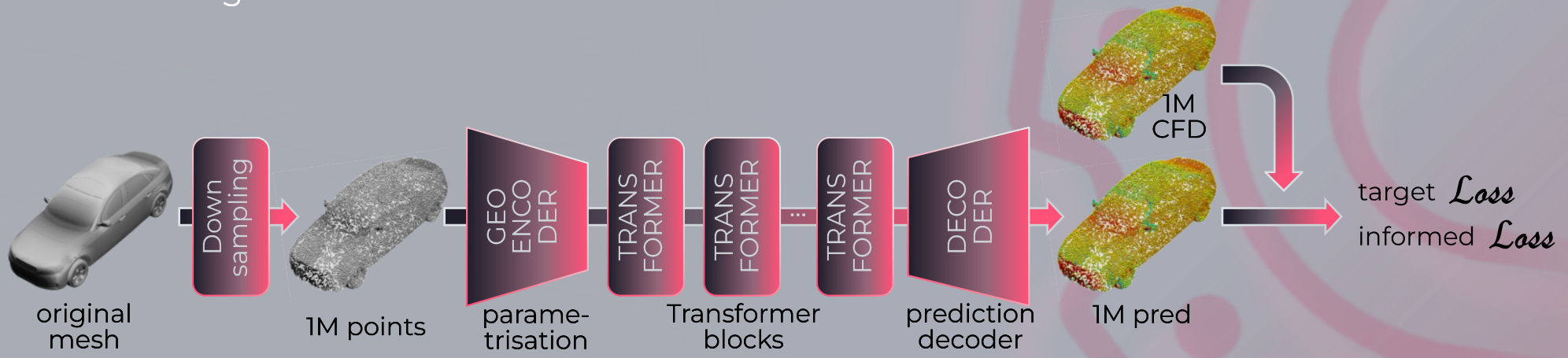
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Best Model Architecture (I/II)

IngeniAI

Model architecture: encoder – transformer – multi-head decoder

- Model architecture easily defined by multiple block selection.
- Full train split – trained with a single 24GB AMD workstation.
- Training: Meshes downsampled to 1M points to limit RAM.
  - Training mode:



- Inputs: Coordinates
  Normals
  Curvature
  . . .
- Outputs: Pressure coefficient
  Shear-stress coefficients

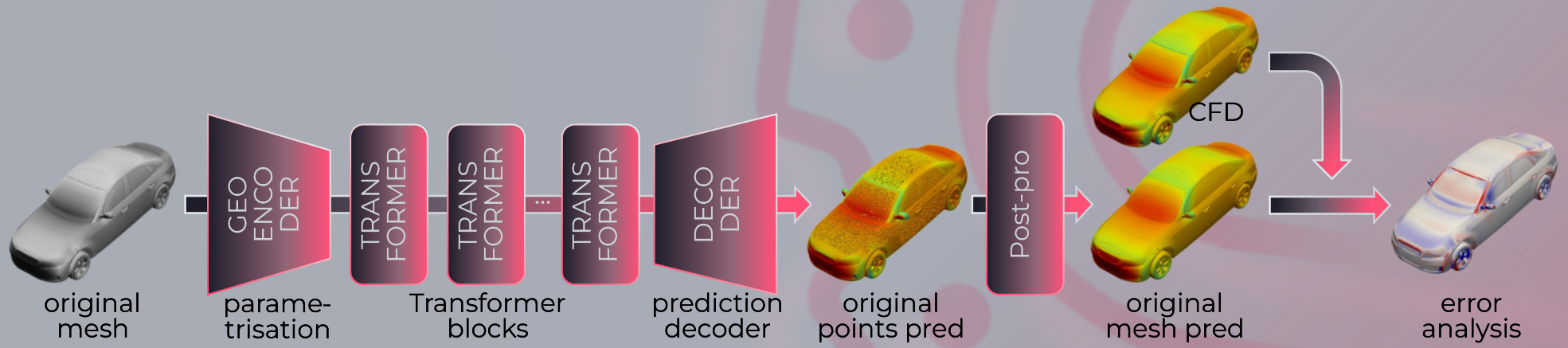
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Best Model Architecture (II/II)

IngeniAI

Model architecture: encoder – transformer – multi-head decoder

- Model architecture easily defined by multiple block selection.
- Test split set.
- Evaluation: predictions on the original mesh sizes.
  - Prediction mode:



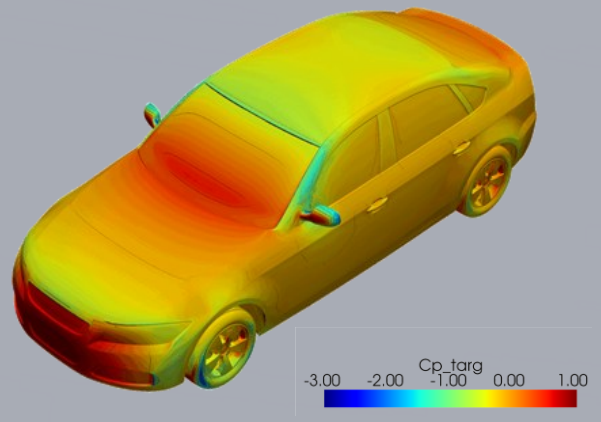
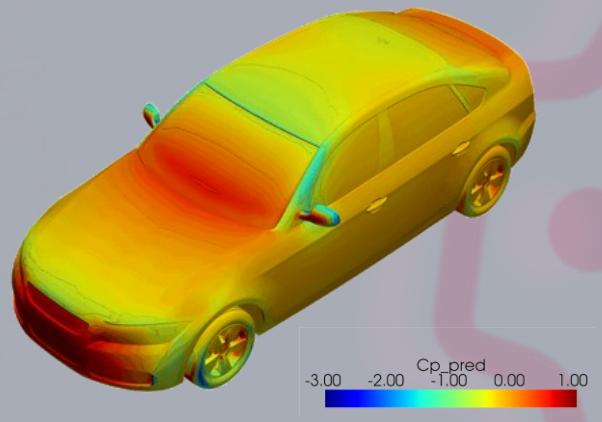
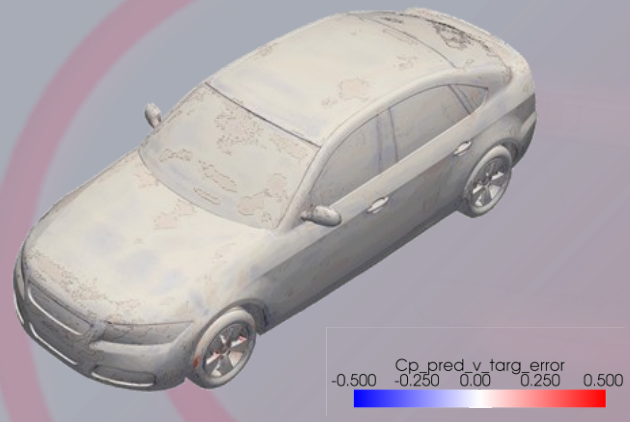
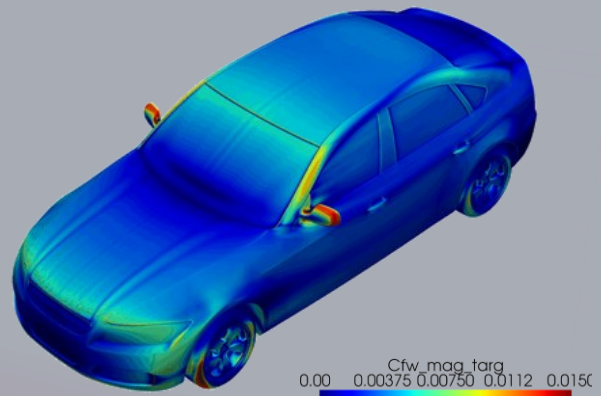
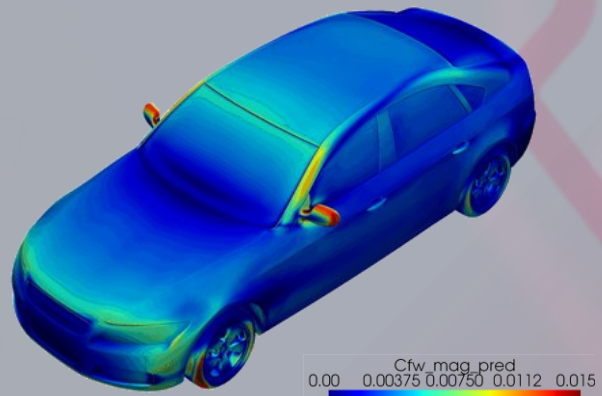
- Inputs: Coordinates
  Normals
  Curvature
  . . .
- Outputs: Pressure coefficient
  Shear-stress coefficients

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Full Train Split – Prediction Results (I/II)

IngeniAI

Surface and shear-stress comparison (test set) – upper body

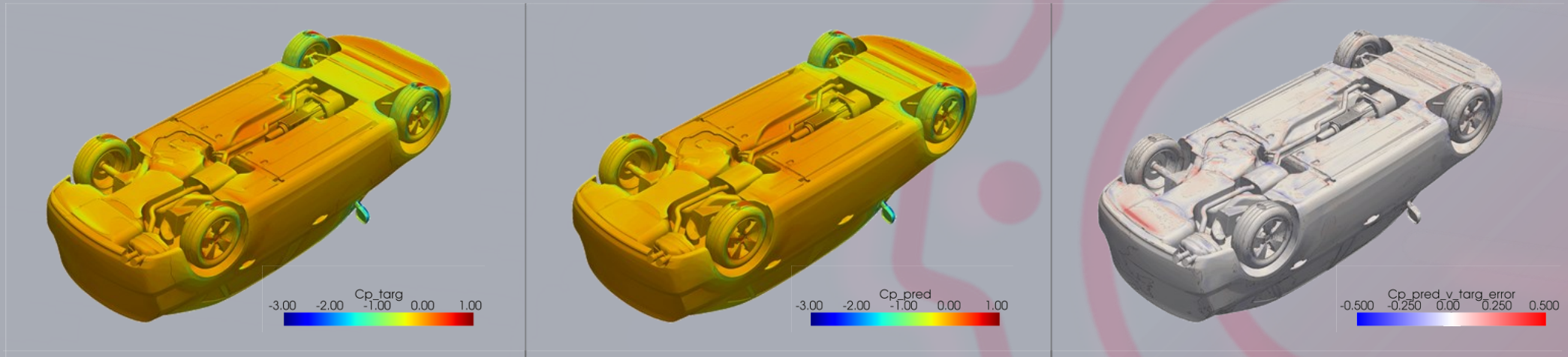
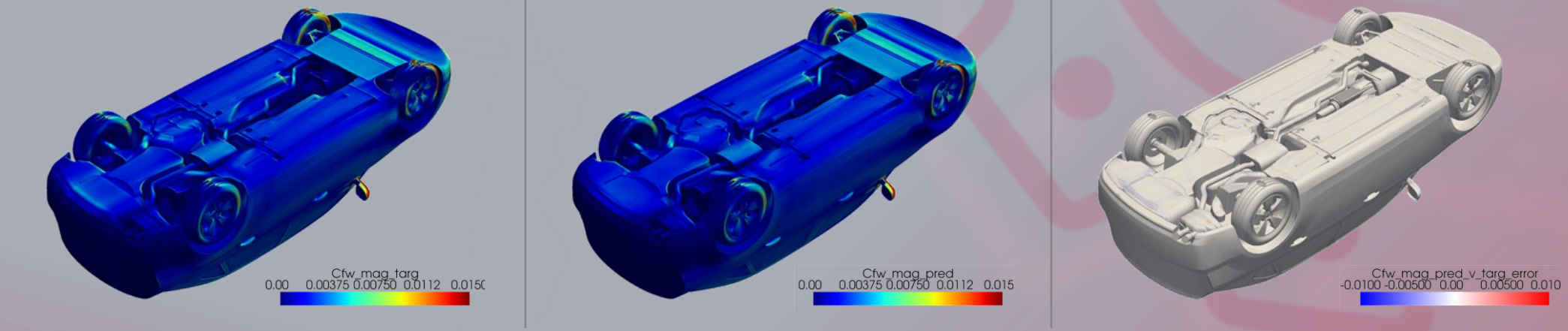
	CFD	Ingeni NetSim	error
Pressure coefficient			
Skin Friction coefficient			

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Full Train Split – Prediction Results (II/II)

IngeniAI

Surface and shear-stress comparison (test set) – under body

	CFD	Ingeni NetSim	error
Pressure coefficient		
Skin Friction coefficient			

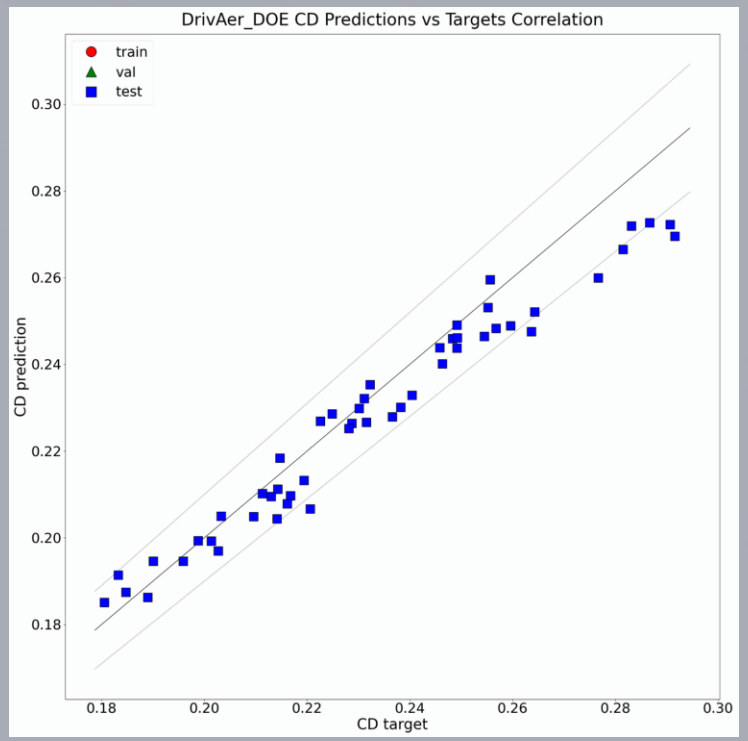
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Full Train Split – Integrated Load Results

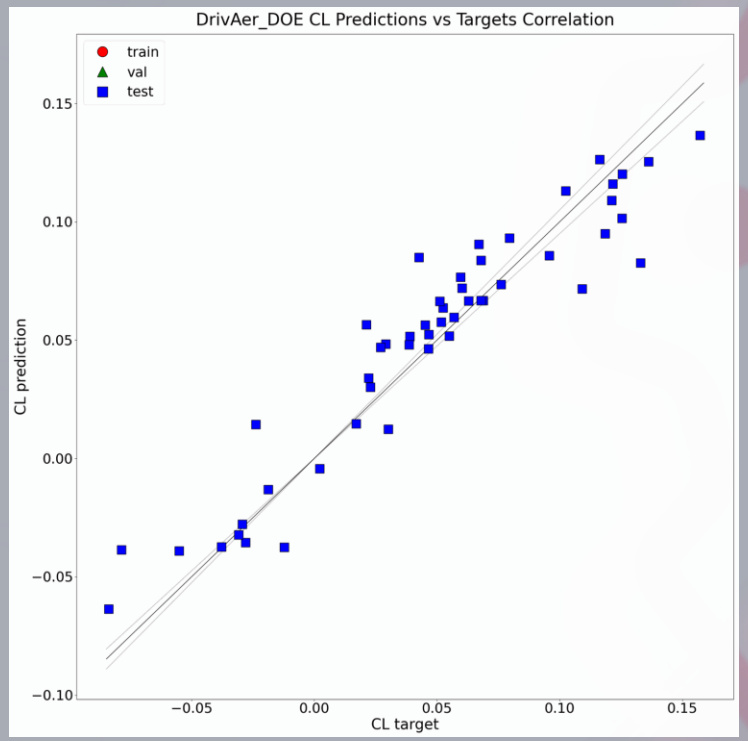
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Analysis of the load coefficients and computing resources

- *Correlation plot for the integrated forces (test set):*



Integrated C_D



Integrated C_L

- *Accuracy analysis on test set:*

	CD	CL	CMy
MAE	0.0064	0.0142	0.0045
MSE	6.7E-05	3.4E-04	3.0E-05
R2-score	**0.964**	**0.900**	**0.990**
Avg error	2.6%	37.9%	4.1%

- *Computing cost:*

Max RAM (400 cases)	58.5 GB
Max GPU (single AMD mi100)	**3.7 GB**
Training time (400 epochs)	6.5 h
Full mesh pred. time	60 s

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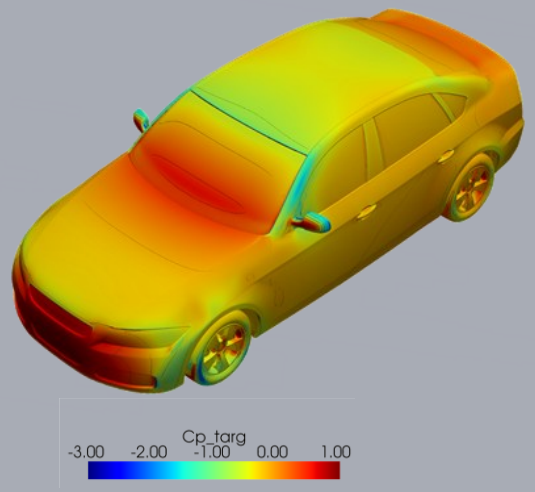
Training Set Sensitivity (I/II)

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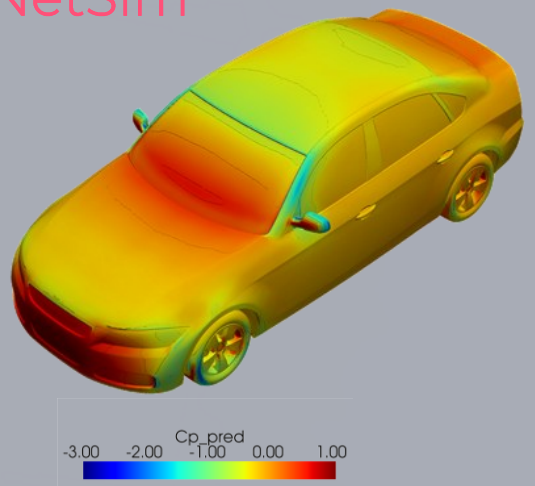
Model performance assessment with reduced data

- *Predicted C_P evolution with train set:*

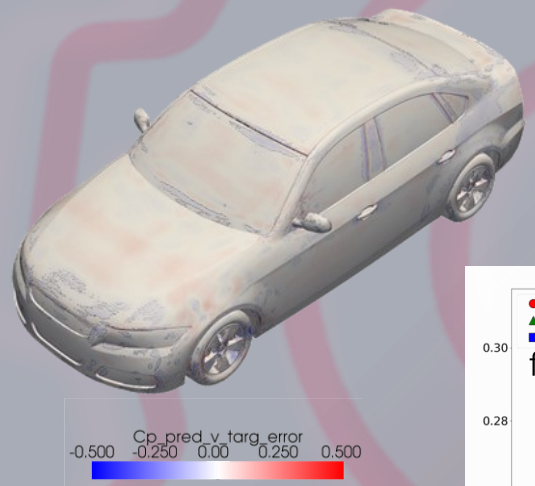
CFD



Ingeni
NetSim

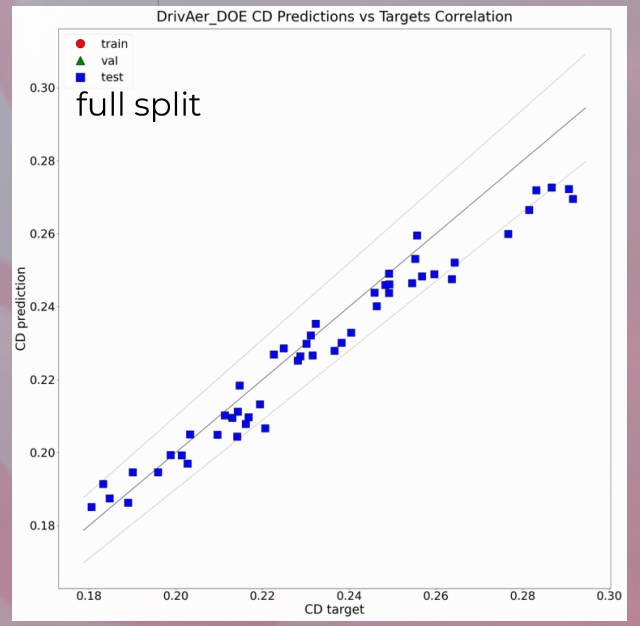


error



full split

- *Integrated C_D Correlation by train set split:*



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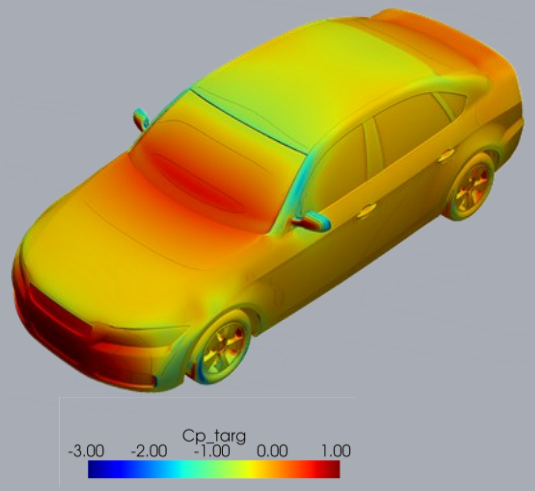
Training Set Sensitivity (I/II)

IngeniAI

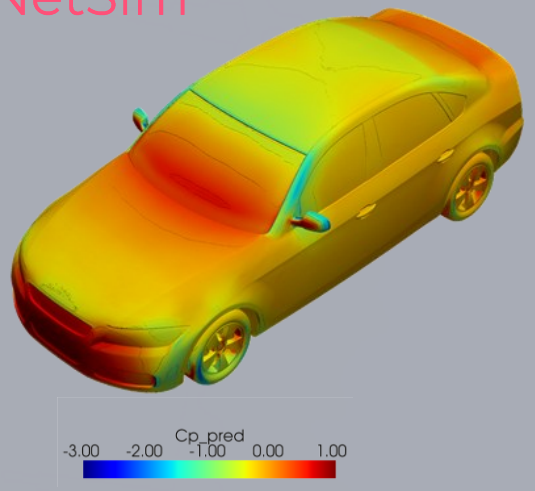
Model performance assessment with reduced data

- *Predicted C_P evolution with train set:*

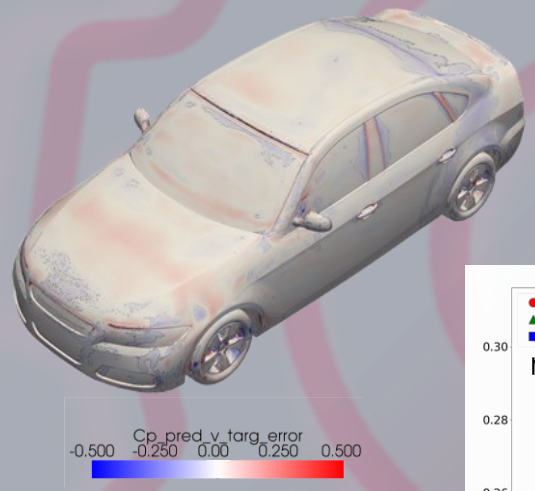
CFD



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NetSim

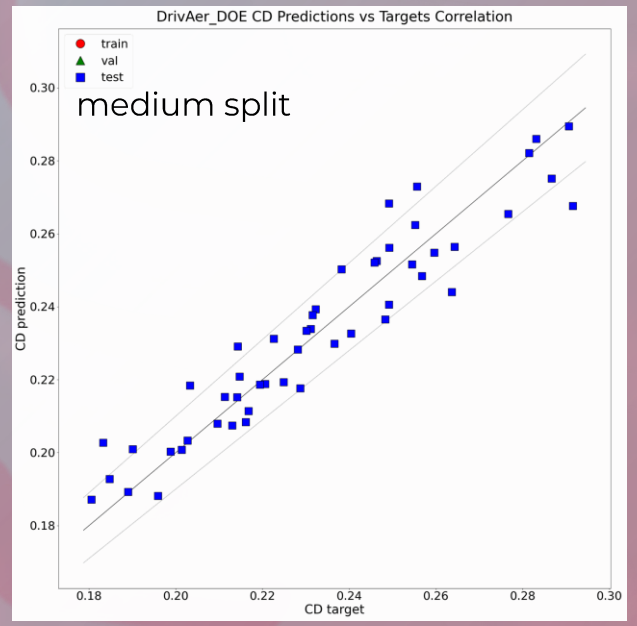


error



medium split

- *Integrated C_D Correlation by train set split:*



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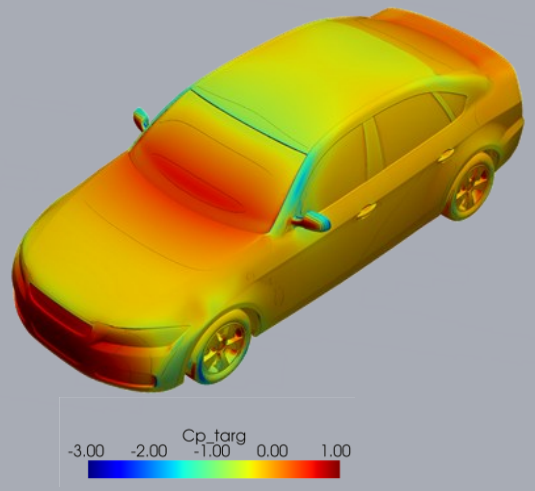
Training Set Sensitivity (I/II)

IngeniAI

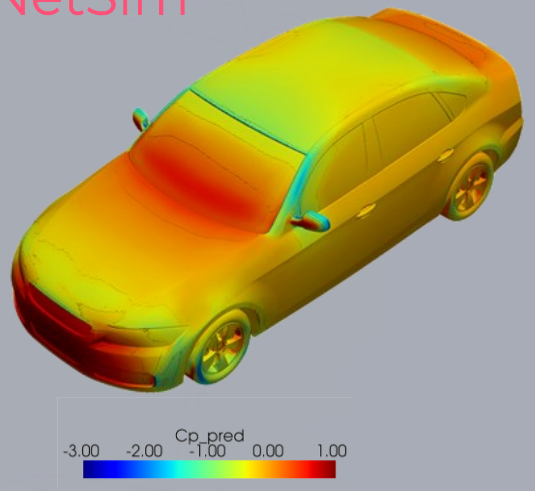
Model performance assessment with reduced data

- *Predicted C_P evolution with train set:*

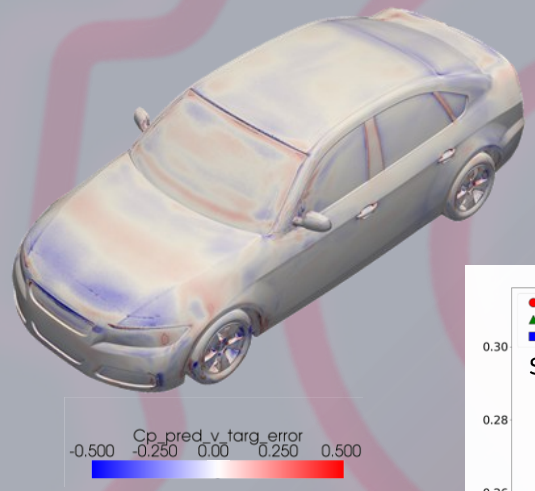
CFD



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NetSim

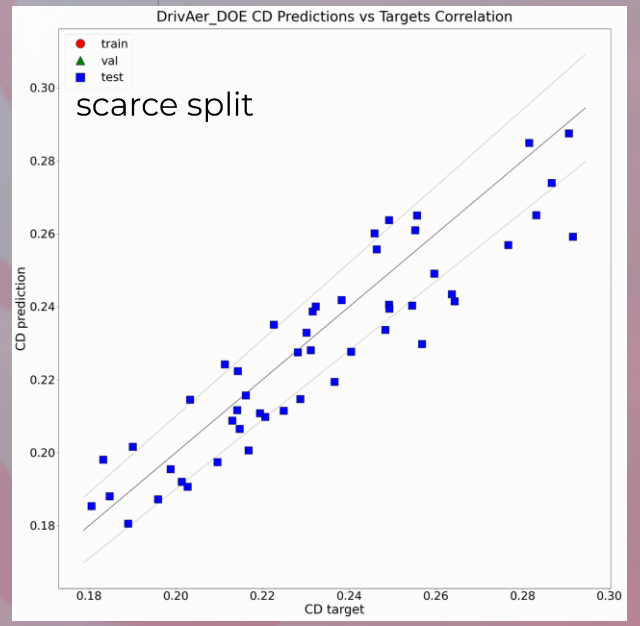


error



scarce split

- *Integrated C_D Correlation by train set split:*



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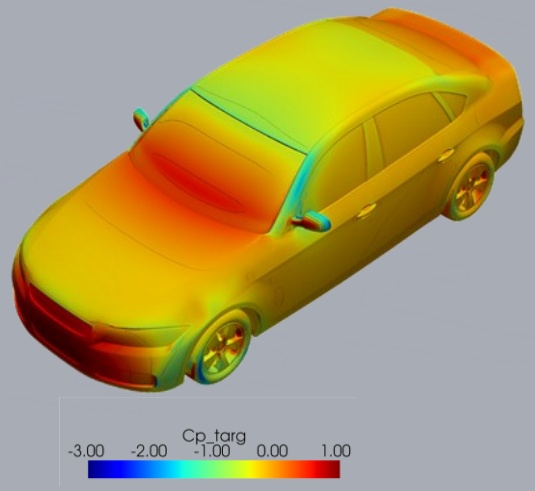
Training Set Sensitivity (I/II)

IngeniAI

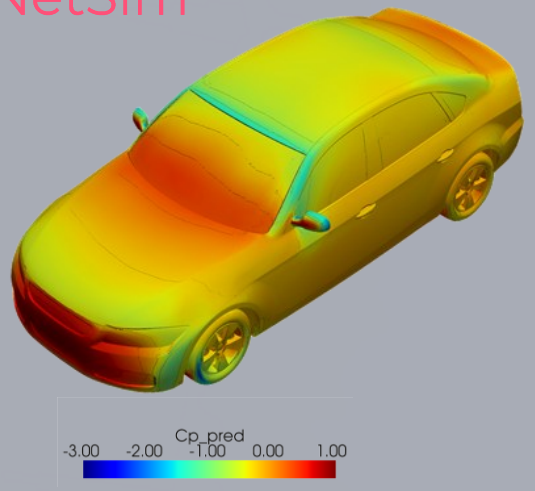
Model performance assessment with reduced data

- *Predicted C_P evolution with train set:*

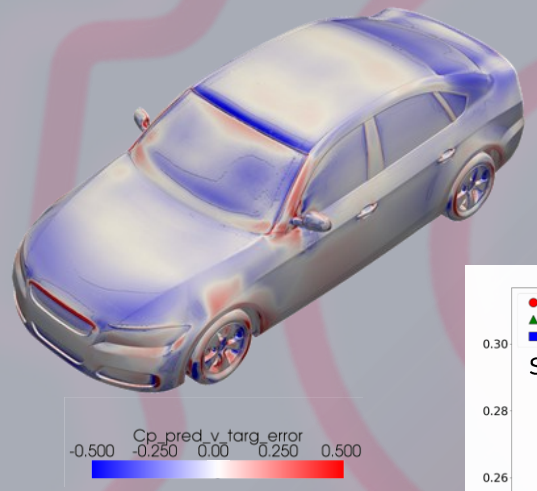
CFD



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NetSim

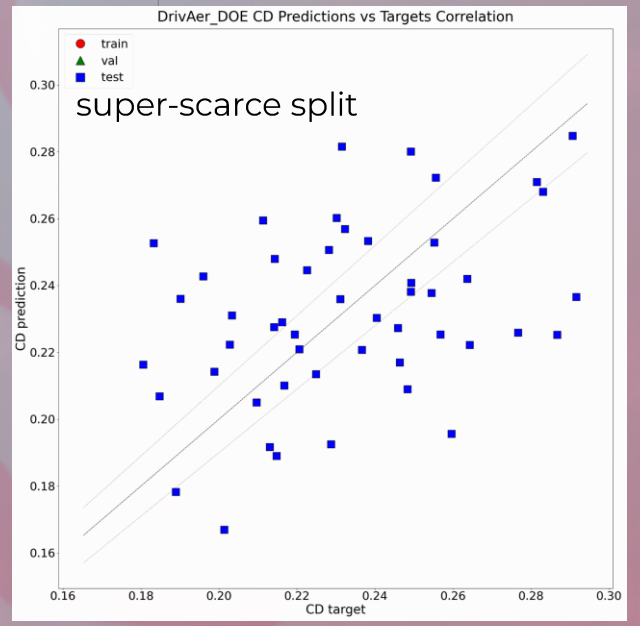


error



super-scarce split

- *Integrated C_D Correlation by train set split:*



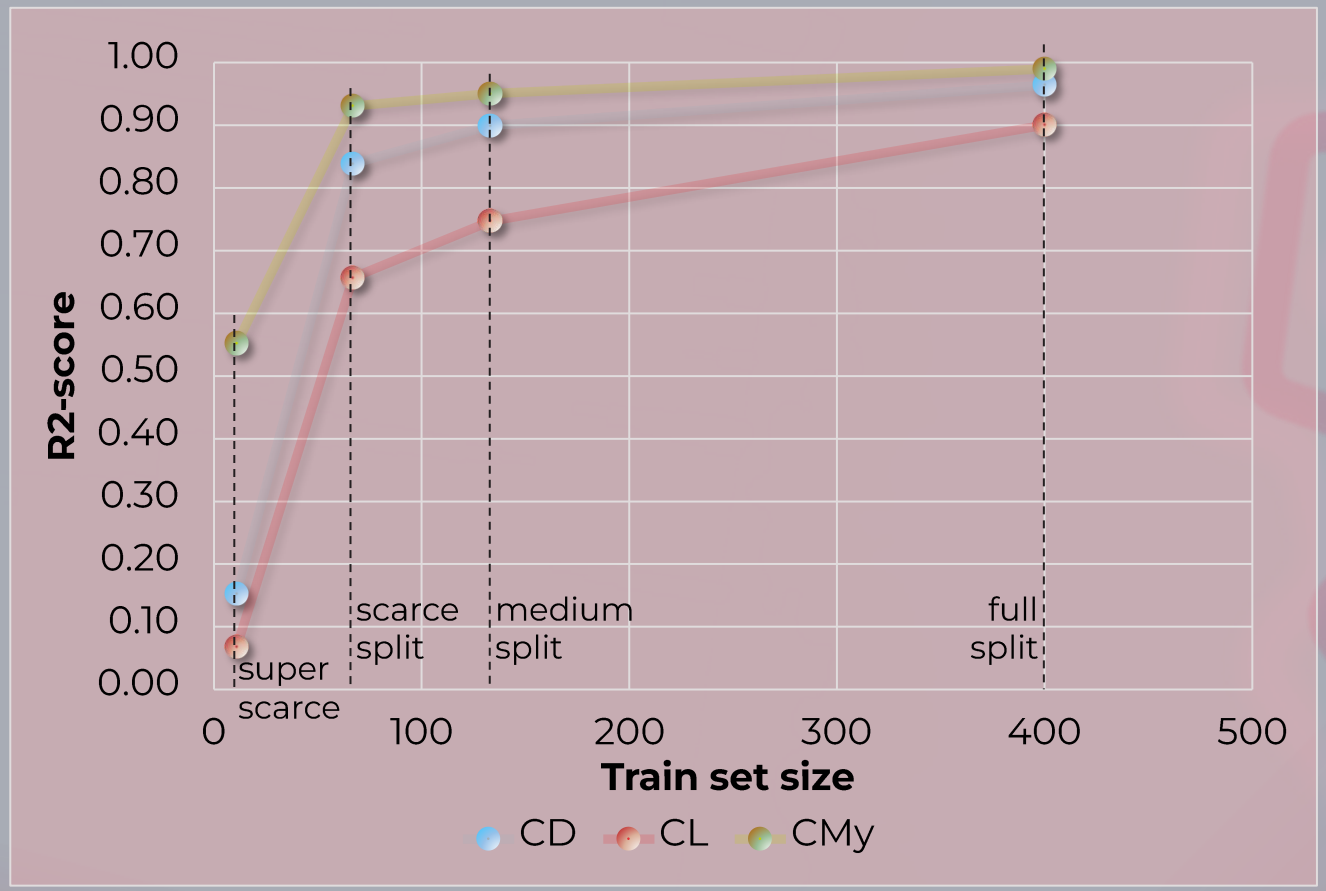
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Training Set Sensitivity (II/II)

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Model performance assessment with reduced data

- *Prediction error sensitivity to train set:*



- *Performance analysis with train set split:*

	Full split	**Medium split**	Scarce split	Super scarce
Cases	400	**133**	67	11
CD MAE	0.006	**0.007**	0.011	0.025
CL MAE	0.014	**0.023**	0.029	0.094
CMy MAE	0.005	**0.009**	0.013	0.023
Train time	6.5 h	**2.2 h**	1.1 h	0.2 h
Max RAM	58.5 GB	**23.5 GB**	15.7 GB	8.5 GB
Max GPU	**3.7 GB**	**3.7 GB**	**3.7 GB**	**3.7 GB**

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Uncertainty Quantification (UQ)

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Assessing confidence in the predictions

- Two uncertainty contributions (medium split):
  - 1) Epistemic Uncertainty:
    - Capture model uncertainty
    - Method: Ensemble models.
  - 2) Aleatoric Uncertainty:
    - Estimate data variability
    - Method: Gaussian loss
- Estimate uncertainty from integrated forces without Monte-Carlo sampling.
- Assess prediction uncertainty as confidence indicator for new designs.

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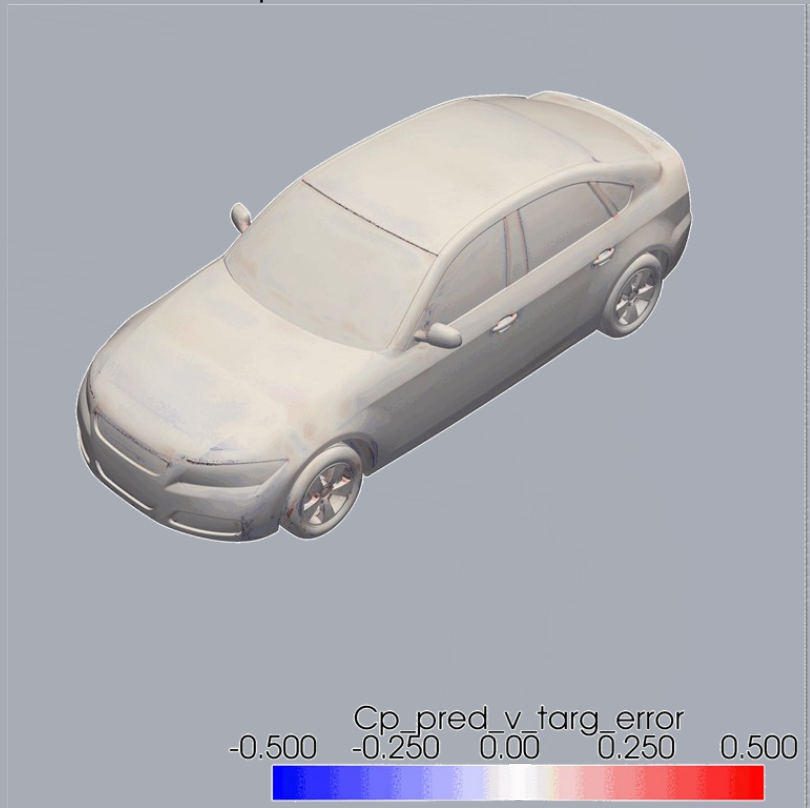
Prediction UQ – Medium Split (I/II)

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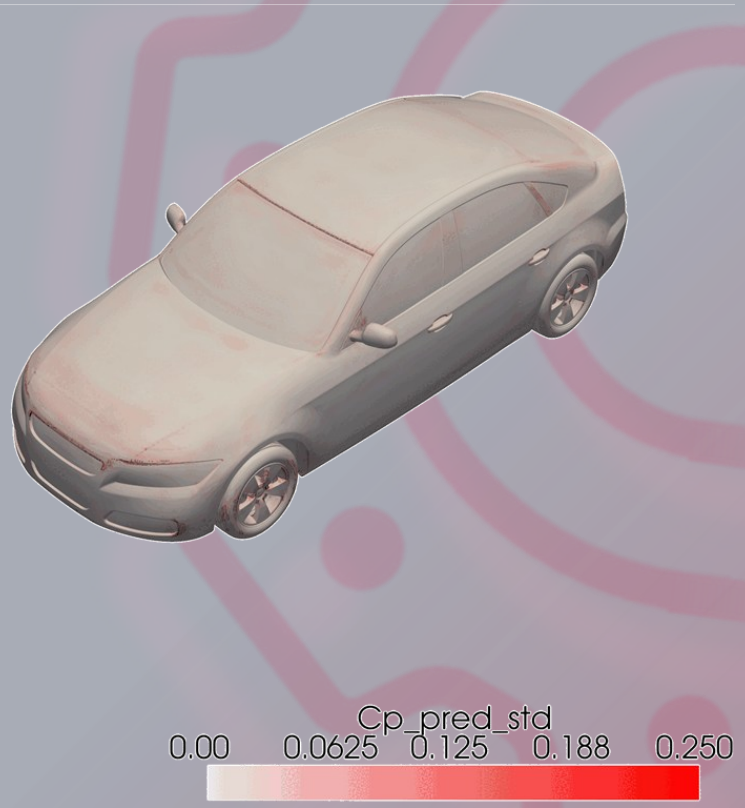
Correlating prediction error with model uncertainty (test set)

- *Error v UQ for Surface C_P – model trained with medium split.*

C_P pred error



C_P pred std. dev.



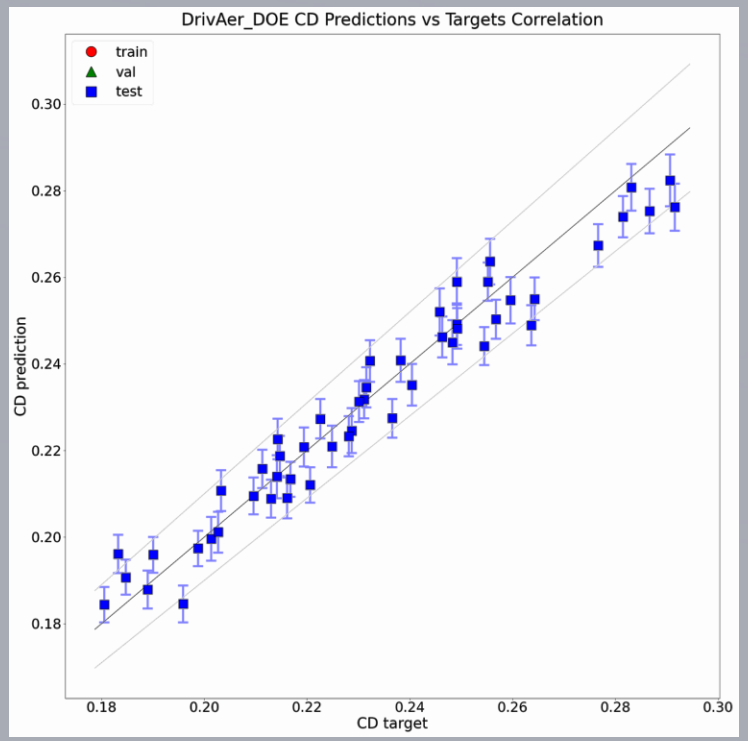
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Prediction UQ – Medium Split (I/II)

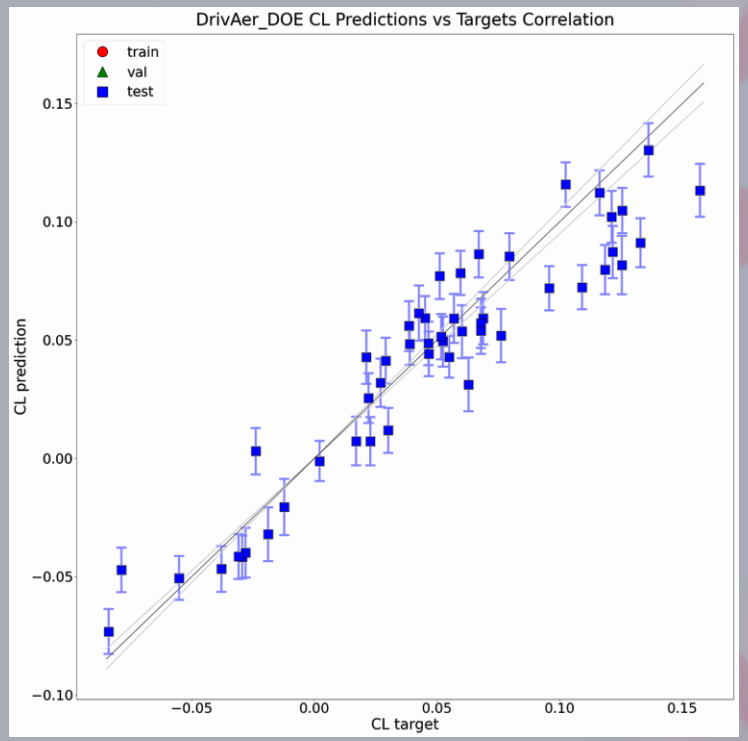
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Confidence analysis of the integrated loads

- *Correlation plot for the integrated forces (test set):*



Integrated C_D



Integrated C_L

- *Accuracy analysis on test set:*

	CD	CL	CMy
MAE	0.0055	0.0160	0.0052
MSE	4.5E-05	3.9E-04	4.0E-05
R2-score	**0.954**	**0.892**	**0.982**
Avg error	2.3%	33.8%	4.7%
95% Cover	48%	34%	54%

- *Computing cost:*

Ensemble Models	10
Max GPU	**3.9 GB**
Training/model (133 cases)	**1.4 h**
Total training time	13.9 h

Accuracy with med split + UQ matches best result with full split!

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Conclusions

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Demonstration of IngeniNetSim on the DrivAerML dataset:

- Surface flow fields
  - Precise mapping of pressure and skin friction distributions across complex vehicle geometries and underbody contours.
- Integrated quantities
  - Global forces and field outputs matched within 5% error margins on DrivAerML.
- Uncertainty bounds
  - Robust prediction uncertainty controlled within 95% bounds.
- Hardware accessibility
  - Flexible and affordable GPU framework enables rapid real-time workstation iteration.

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AI-Powered Engineering Innovations

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